Teilchenstrahlgerät

Publication number: DE19828476
Publication date: 1999-12-30
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Classification:
- international: ***H01J37/244; H01J37/29;*** **H01J37/244; H01J37/26;** (IPC1-7): H01J37/244; H01J37/28
- European: H01J37/244
Application number: DE19981028476 19980626
Priority number(s): DE19981028476 19980626

Also published as:

- EP0969495 (A2)
- US6498345 (B1)
- JP2000030654 (A)
- EP0969495 (A3)

Abstract not available for DE19828476

Translation of DE 198 28 476

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Particle beam devices with ions or electrons are used preferentially for the illustration, analysis and treatment of sample surfaces. The imaging a focused particle beam will become rasterförmig led across the sample surface and the signals developing during the reciprocal effect of the Primärteilchen with the sample seized and assigned to the respective developing place. Apart from a high local dissolution, which is reached by a small diameter of the particle beam in the level of the sample, as high an efficiency of the detection of the different signals as possible is necessary.

The dissolution of Korpuskularstrahlgeräten is in principle best, if the sample very close at the objective lens is or even within this lens. This has the consequence that the detection system must be arranged to the proof of secondary and/or backscattered particles within the objective lens or within a field-free range between the objective lens and the source of particle. The best dissolution, in particular with low particle energies, is obtained with arrangements, with which the particles in the emitter generation system are accelerated first on a high energy and braked at the end of the particle-optical arrangement in an objective lens or in the range between the objective lens and the sample on the desired final energy.

Appropriate particle beam devices are for example in the USA 4.831.266 and the USA 4.926.054 described. By combination of an electrostatic and a magnetic field in the objective lens even with low particle energies a very high resolution is obtained. In addition or otherwise the particles in opposite direction, emitted scattered back by the sample, by the sample, are accelerated by the electrostatic field and illustrated on a circular scintillation detector above the objective lens. In US 4.896.036 a similar arrangement with a likewise circular detector is described, with which however the objective lens is a purely electrostatic lens.

With these well-known systems it turned out as unfavorable that the circular detector with scintillator and glass light conductor a relatively large opening of approx. 2-3 mm to exhibit must, so that the primary particle beam is not obstructed by the circular detector. Calculations and experiments resulted in the fact that the central opening of the detector up to approximately 80% of the particles developing at the sample it passes through and thus is not detected. The detected signal is very weak thereby. In addition will the detected particles only integral seized, and cannot therefore after energy and starting angle be separated.

From an essay in Nuclear of instrument & Methods in Physics Research A, Volium 363, pages 31-42, (1995) it is well-known to steer by suitable arrangement of two vienna filters, by the sample emitted or at the sample scattered back particles into axle-far of ranges without the primary particle beam is noticeably affected. This measure leads to an improvement that detection-efficiently, a distinction of the detected signals after starting angle etc. is not however also here possible.

In the USA 5.644.132 a scanning electron microscope is described, with which the circular detector exhibits several circular partitionings. By this allocation the electrons, which are compared with the secondary electrons emphasis-moderately more strongly in the ohnear range provable, scattered back at the sample, are by which oh-further secondary electrons are separated. In connection with a remark example thereby also the possibility is addressed that for assembly reasons the internal circular detector and the outside circular detector can be arranged easily transferred toward the Z-axis. Such an circular allocation of the detector permits in principle a separation after of the detected electrons their starting angle with the withdrawal from the sample. The problem that a large portion of the secondary electrons and the scattered back electrons is transmitted by the central drilling range and is not therefore at all proven, cannot be solved by this circular partitioning of the detector however.

It is the goal of the available invention of improving with particle beam equipment the detection of the Sekundärteilchen emitted by the sample and the particles scattered back at the sample. In addition a selection or an allocation after of the detected particles is to be possible their starting angle.

This goal is solved according to invention by particle beam equipment with the characteristics of the requirement 1. Favourable arrangements of the invention result from the characteristics of the dependent requirements.

With the particle beam equipment according to invention two detectors for by the object scattered back or by the object the emitted particles are to each other transferred arranged toward the Z-axis of the particle beam equipment. The distance toward the Z-axis between both detectors amounts to thereby at least 25% of the distance between the object-lateral detector and the focus level of the objective, by which the particle beam is focused on the sample. The rehearse-lateral detector serves thereby for detection those particles, which withdraw under a relatively large solid angle from the sample, while the pour-lateral detector serves those particles, which withdraw under a relatively small solid angle from the sample and through for depress primaryparticle beam through the rehearse-lateral detector planned opening through this transmit for detection. Transmitted particles can be proven by the axially shifted arrangement of both detectors with the pour-lateral detector even then by the central drilling of the object-lateral detector, if both detectors central openings with same diameter exhibit. Preferably should however the central opening for depresses primaryparticle beam with the pour-lateral detector at the most one third of the diameter of the central drilling of the object-lateral detector to amount to. According to small drilling diameters of for example under 0.2 mm by the pour-lateral detector are then possible, if this detector is designed as conversion screen, at which with the impact of high-energy particles themselves again for secondary electrons develop. The secondary electrons withdrawing from the conversion screen are then detected by a laterally arranged conventional detector, which produces an electrostatic suction field for the secondary electrons withdrawing from the conversion screen. The material of the conversion screen should a relatively light element with an ordinal number < = 20 its, z. B. Aluminum or carbon, since such light elements exhibit a relatively high secondary electron yield.

As is the case for the state of the art initially specified both detectors exhibit one symmetrically to the Z-axis trained, circular detection surface. In contrast to the state of the art initially mentioned however the outside diameter of the detection surface of the pour-lateral detector should be larger than the diameter of the central drilling of the rehearse-lateral detector.

As far as the pour-lateral detector only a very small, which depresses aperture of the primary jet limiting drilling for the primary jet exhibits, should be taken up this detector at an adjuster, the one adjustment of the detector in the two to the Z-axis senkrechten directions permitted.

For the evaluation of the signals detected with both detectors signal processing electronics can be intended, from the detector signals the output signals produced, which correspond to linear combinations of both detector signals. The influences of the surface topography of the sample can be strengthened and charge contrast pictures be produced by education of appropriate linear combinations. This is of advantage in particular if thin layers are also examined for the matrix of different conductivity in the particle beam equipment. The coefficients of the linear combinations should be freely selectable thereby by the user of the particle beam equipment.

In the following details of the invention are more near described on the basis the remark example of a scanning electron microscope, represented in the figures.

In detail show:

Fig. 1 the principle sketch of a scanning electron microscope on average, in which the invention is realized; and

Fig. 2 a diagram of the electron trajectories for secondary electrons as a function of the starting angle at the sample surface.

The particle beam producer with the particle beam equipment according to invention consists of a cathode (1), emitting the particles, an extraction electrode (2) and an anode (3). If the particle beam equipment according to invention is designed as scanning electron microscope, preferably the cathode (1) is a thermal field emitter. From the cathode (1) withdrawing particles become by in the Fig. 1 not represented difference of potential between the cathode (1) and the anode (3) on the anode potential accelerates.

The anode (3) forms at the same time the pour-lateral end of the jet guide tube (4). This jet guide tube (4) from electrically leading material is led by the drilling by the pole pieces (5) of a Magnetlinse working as objective and is thickened trained at the object-lateral end (8) as tubing lens. This thickened object-lateral end of the jet guide tube (4) ends only behind the pole piece gap (ä) to the Magnetlinse, whose coils with (6) are designated. The jet guide tube a single electrode (9) is subordinate, which forms an electrostatic delay mechanism together with the tubing electrode (8) of the jet guide tube (4). The tubing electrode (8) lies together with the entire jet guide tube (4) on the anode potential, while the single electrode (9) and the sample (10) are on a potential lower in relation to the anode potential, so that the particles are braked after withdrawal from the jet guide tube on the desired lower energy.

In the drilling of the pole piece (5) of the objective lens, at height of the pole piece gap (ä) still another deflection system (7) is arranged, by which the initiating electron jet focused by the objective (5) on the sample (10) is diverted perpendicularly to the dash-dotted-represented Z-axis to scanning the sample (10).

If like straight described, has in Fig. 1 represented scanning electron microscope a structure, as this is described in the German patent application 197 32 093,7. On this earlier registration extraction electrode (2) is, anode also concerning the potential admission of cathode (1), (3) and brake electrode (9) referred.

Alternatively to the representation in Fig. 1 can end the jet guide tube (4) also on height of the pole piece gap (ä) and be arranged the deceleration electrode (9) also in approximately at height of the pole piece gap (ä). The deceleration of the Primärteilchen on the desired Auftreffenergie takes place then already within the objective, so that the magnetic field of the objective lens and the electrostatic delay field overlay spatially.

For the detection from the sample (10) withdrawing particles, the scattered back electrons and the secondary electrons, are to each other transferred arranged within the jet guide tube (4) between the jet producer and the objective (5, 6) of the two detectors toward the Z-axis. Both detectors have a circular, essentially symmetrically detection surface arranged to the Z-axis. The object-lateral detector is trained thereby in well-known way as scintillator with a glass light conductor (11) and an optical detector (12). The glass light conductor (11) serves thereby for conversions of the hitting electrons in photons and at the same time for the line of the photons for the optical detector (12). There the glass light conductors for a high efficiency of the lighting lead a relatively large thickness toward the Z-axis of approx. 5-7 mm, exhibits the drilling exhibits in the glass light conductor for depresses the primary jet a diameter of 2-3 mm, so that the primary jet is not affected by the glass light conductor. The rehearse-lateral detector (11, 12) serves those particles, which withdraw under a relatively large solid angle from the sample (10) for detection. It concerns primarily secondary electrons, whose kinetic energy is with the withdrawal from the sample (10) in the range between 1-50 eV with a maximum with 2-4 eV. At the sample (10) scattered back electrons, which exhibit a relatively high kinetic energy compared with the secondary electrons with the withdrawal from the sample (10), are seized against it by the detector (11) only to a very small portion. Because the scattered back electrons withdrawing relative to the Z-axis in a solid angle of 0-5 DEG from the sample transmit by the hole by the detector (11) and under an angle of > 15 DEG from the sample withdrawing electrons meet already within the pole piece range the jet guide tube (4) and are absorbed there.

The pour-lateral detector contains a circular conversion screen (13), which is clearly toward the Z-axis beabstandet at an adjusting device (14) taken up by the rehearse-lateral detector (11). By the adjusting device (14) the conversion screen (13) in the two directions is perpendicularly to the Z-axis adjustable. The conversion screen is a thin plate with a thickness of 0.1-1 mm from a material with small ordinal number and has a small central hole for depresses the initiating electron jet, whereby the hole diameter amounts to about 200-400 mu m. Due to the small hole diameter the conversion screen (13) works aperture-limiting for the initiating electron jet and works thereby at the same time as aperture diaphragm.

The conversion screen consists of a material with small ordinal number, for example aluminum, thus with good reason high efficiency on the conversion screen (13) hitting electrons again secondary electrons releases. For the detection of these secondary electrons released by the conversion screen rehearse-laterally the conversion screen (13) laterally by the Z-axis a Everhart Thornley detector (15) is arranged. This Everhart Thornley detector is over a grid electrode on a potential, which is higher about 6-10 kV than the potential of the conversion screen (13), which is on anode potential. The secondary electrons withdrawing from the conversion screen (13) are sucked off and accelerated by this difference of potential in the direction of the detector (15).

The distance along the Z-axis between the detection level of the rehearse-lateral detector (11) and the conversion screen (13) amounts to at least 25%, preferably about 50-75% of the distance between the detection surface of the rehearse-lateral detector (11) and the sample (10). The outside diameter of the conversion screen (13) is at the same time larger than the diameter of the opening by the rehearse-lateral detector (11). By this geometrical arrangement it is ensured that a majority and of the electrons (20), transmitting withdrawing from the sample (10), by the opening of the rehearse-lateral detector (11), by the pour-lateral detector (13) it is detected.

With the two toward the Z-axis shifts arranged detectors obtained effect is on the basis the Fig. 2 illustrates. There the courses for secondary electrons with a kinetic energy of 3, withdrawing from the sample under different angles, are laid on eV with the withdrawal from the sample for the case that the energy primaryparticle beam with the impact on the sample of the 1 amounts to keV and the distance between the sample and the objective lens 5 mm. For better illustration the distance of the electron trajectories from the Z-axis is superelevated and after their cut with the Z-axis reflected represented the course of the electrons around a factor 50. The distance between the detection level of the rehearse-lateral detector (11) and the sample amounts to 100 mm. The radius of the central opening by the rehearse-lateral detector (11) amounts to 1 mm. As results from the diagram of the course processes, with the rehearse-lateral detector (11) such secondary electrons are only detected, which > under an angle of; about 35 DEG from the sample (10) withdraw. With a leading sample (10) with even sample surface the different possible starting angles are distributed with the withdrawal from the sample according to a Lambert' cosine distribution. From it it results that about 40% of the secondary electrons withdrawing from the sample exhibit an angle with the withdrawal from the sample relative to the Z-axis of under 30 DEG, so that about 40% of the secondary electrons withdrawing from the sample cannot be seized by the rehearse-lateral detector. In case of a non conductive sample surface in practice due to local loading effects nearly all electrons with very small angles are emitted to the surface-normal, so that in this in practice very important case even only less than 20% of the secondary electrons with the rehearse-lateral detector (11), withdrawing from the sample, can be proven.

A majority of the secondary electrons transmitted by the opening of the rehearse-lateral detector (11) is proven during the arrangement in accordance with the invention by the pour-lateral detector (13). This pour-lateral detector (13) points in the Fig. 2 a distance from 70 mm to the detection level of the rehearse-lateral detector (11) up. The diameter of the pour-lateral detector (13) and/or. its detection surface is larger thereby than the diameter of the central opening in the rehearse-lateral detector (11). In addition the pour-lateral detector (13) exhibits only a very small central opening with a radius of 0.1 mm, so that this detector screen for the primary particle beam works aperture-limiting.

Like the course processes in Fig. 2 is entnehmbar, can with the pour-lateral detector also such secondary electrons be proven, which withdraw under an angle of under 35% from the sample. If one summarizes altogether the secondary electrons seized with both detectors (11, 13), then it results that during the arrangement according to invention of the detectors all secondary electrons are seized, under an angle of > 2-3 DEG from the sample withdraw. The signal gain by the second, pour-lateral detector in relation to the same arrangement with only the rehearse-lateral detector amounts to in case of a leading even sample surface about 40% and in case of non conductive sample surfaces up to 80%.

In addition can be strengthened by suitable mixture, in particular the humming and difference formation of the output signals of both detectors (11, 13) the surface topography and produced a charge contrast. For this mixture of the two detector signals (A, b) the particle beam equipment points in Fig. 1 a signal processing (17) up, the linear combinations arbitrarily given in advance of both detector signals (A, b) forms. The coefficients of the linear combination are arbitrarily given in advance thereby on the part of the user, which in the Fig. 1 by the arrow with the small letters (m, n) is suggested. The output signal of signal processing (17) is represented in the following as function of the place on the sample (10) on a monitor (18) or is not put down for a large image processing in a represented bit map memory.

The described arrangement with two is particularly useful toward the Z-axis clearly shifts arranged circular detectors, from which the rehearse-further exhibits only a very small central opening, in cases in those the primary energy of the electrons of middle energies over 5 keV to down to lowest primary energies under 200 eV with the impact on the sample is variable. Because it was shown that with primary energies under 200 eV, in particular within the primary energy range 20-100 eV, a very large portion of the secondary electrons independently of their

angle of outlet from the sample by the objective it is diverted in such a way that its courses are not provable in the range of the rehearse-lateral detector very close at the Z-axis run and therefore with this detector. These secondary electrons are efficiently detected with the pour-lateral detector. At the same time the rehearse-lateral detector makes the proof possible of those secondary electrons, which withdraw under a large angle relative to the Z-axis from the sample with higher primary energies.

The invention makes not only a separation after for secondary electrons possible their angle of outlet from the sample but also a separation after their energy with the withdrawal from the sample. Because since the courses of the low-energy secondary electrons run independently of their angle of outlet more near at the Z-axis than the courses high suppl. tables of the secondary electrons, with the pour-lateral detector primarily low-energy and with the rehearse-lateral detector primarily high suppl. tables secondary electrons are proven.

On the basis the remark example represented in the figures the invention for the case was described that the Primärteilchen are electrons. With application of the invention to positively charged particles only the polarity of the different potentials needs to be adapted on the changed sign of the particle charge.

Further the objective does not have to be compellingly as Magnetlinse trained. It is also conceivable and in particular on use of heavy corpuscles such as ions as Primärteilchen favourable to use for the focusing of the corpuscles an electrostatic Einzellinse. Such electrostatic Einzellinse can be developed in well-known way from three following each other electrodes, from which the two outside electrodes at the potential of the jet guide tube lie and which middle electrode corresponds to the cathode potential then at a potential concerning the polarity, however is somewhat according to amount smaller. Such electrostatic Einzellinse leads contrary to the electrostatic Immersionslinse to no change of the particle energy.

Furthermore the particle beam equipment can exhibit also further particle-optical illustration elements, like z. B. between the source of particle and the pour-lateral detector an arranged, in or multi-level condensor lens for varying the probe size on the sample or the aperture of the particle beam.

Claims

1. Particle beam equipment, in particular electron beam equipment, with a jet producer (1, 2, 3), an objective lens (5, ä, 6) to the focusing of a particle beam on a sample (10) and two detectors arranged between the jet producer and the focus level of the objective (5, ä, 6) (11, 12, 13, 15, 16) for of the object (10) scattered back or emitted particles (19, 20), whereby the detectors (11, 12, 13, 15, 16) are of each other transferred arranged toward the Z-axis and the distance between both detectors at least 25% of the distance between the object-lateral detector (11, 12) and the focus level of the objective amounts to.

2. Particle beam equipment according to requirement 1, whereby the outside diameter of the particle-sensitive surface of the pour-lateral detector (13, 15, 16) is larger than the diameter of the central drilling of the rehearse-lateral detector (11, 12).

3. Particle beam equipment according to requirement 1 or 2, whereby both detectors exhibit one symmetrically to the Z-axis arranged, circular detection surface (11, 13).

4. Particle beam equipment according to requirement 2 or 3, whereby the central opening for depresses the primary jet through pour-lateral detector (13, 15, 16) at the most one third of the central opening of the object-lateral detector (11, 12) amounts to.

5. Particle beam equipment after one of the requirements 1-4, whereby the pour-lateral detector (13, 15, 16) is designed as conversion screen (13) with a scintillation detector (15, 16), and whereby the scintillation detector (15, 16) withdrawing charged particles exhibits a suction field for from the conversion screen (13).

6. Particle beam equipment according to requirement 5, whereby the conversion screen (13) consists of a material with an ordinal number of at the most 20.

7. Particle beam equipment according to requirement 5 or 6, whereby the conversion screen (13) at an adjuster (14) is taken up.

8. Particle beam equipment after one of the requirements 1-7, whereby for the output signals of both detectors (11, 12, 13, 15, 16) a signal processing (17) is intended, from the detector signals the output signals produces, which correspond to linear combinations of both detector signals.

9. Particle beam equipment according to requirement 8, whereby the coefficients (m, n) of the linear combination of the user are freely selectable.